The Carbon Budget Model

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Background

The carbon budget (Trofymow and Blackwell, in these proceedings) project is attempting to compare the carbon budgets of old-growth forests with those in forests of younger seral stages. Sites have been located on the western and eastern sides of southern Vancouver Island. In each site there are plots representing the four age classes in the chronosequence. The sampling of carbon from trees and course woody debris in soils and the forest floor will provide data for comparing the different age classes and assessing their rates of carbon storage. A model was wanted to allow us to quantify the processes occurring in the turnover of carbon and to investigate various management interventions on carbon cycling.

Purpose

The model will be used in two related contexts: 1) to compare the carbon cycling dynamics among the four age classes in the chronosequence and to assess the characteristics of old-growth forests which may be unique and desirable; and 2) to assess the effects of management interventions on the ability of the forest to sequester carbon from the atmosphere and retain it.

Type of Model Required

Forest models generally can be divided into two types: mensurational (predictive) and mechanistic (process-oriented) models. Mensurational models rely heavily on growth data and assume that conditions do not change over the period of prediction. They are usually good predictors of growth and future volume but give little or no insight into forest processes. Mechanistic models are generally poor predictors of volume, since the final outputs are the result of a chain of processes, each of which is modelled with some degree of error. The strength of mechanistic models lies in their flexibility and responsiveness to changing conditions, and thus they are ideally suited to investigating scientific hypotheses and the effects of management interventions. For these reasons we have chosen to develop a process-oriented model to address the characteristics of different aged stands that go beyond the strictly mensurational aspects. This flexibility is expected to facilitate investigation of some of the effects of climate change.

Model Development

We have chosen to use the Shawnigan model (SHAWN) as the basis of the new carbon budget model. Not only is SHAWN a process model, but it was specifically meant to model the Shawnigan experimental trees, with all their variations in treatment. This site forms one of the seres in the chronosequence. The model is also in a sufficiently advanced state that much of the work for the carbon budget model has already been done using SHAWN as its basis.

SHAWN started its life as a site model (Barclay and Hall 1986), with trees not being explicitly identified. Eventually information on the trees from 25 plots at the Shawnigan experimental site were incorporated into the model, including their known diameters, heights, heights to the live crown, and positions. The processes that operated on the total amounts of wood, foliage, etc., now operate on each tree individually. Competition among trees was modelled by Arney's Competitive Stress Index (CSI) (Arney 1973), using relationships derived subsequently from the Shawnigan data (Barclay and Layton 1990). Thus, SHAWN is now a distance-dependent individual tree model which has nitrogen as its driving force, modified by stand density, temperature, water availability, and soil processes.

In the carbon budget model, we have taken SHAWN and incorporated a more complete carbon tallying facility. The next step is to complete and incorporate an updated water balance and temperature submodel based on information from Campbell (1985). After that we will construct and incorporate a more realistic soil decomposition submodel similar to that used in the Canada forest sector carbon budget model (Kurz *et al.* 1992). Finally, a user-friendly interface will be installed to allow its use as a gaming model to investigate a variety of possible management interventions.

Use of the Model

A parameter sensitivity analysis will eventually be done on the model similar to, but more extensive than, that presented by Barclay and Hall (1986). This analysis will indicate parameters that need careful measurement, processes and attributes that are particularly sensitive to management intervention, and the general behaviour of the model. It will also identify conditions which may adversely affect certain seral stages of the forest. In addition, it will be used as a gaming tool to assess the efficacy of various interventions on the ability of the forest to store and sequester carbon. Ultimately, we plan to publish a set of guidelines to facilitate carbon storage.

Validation

1. The output of each of the major submodels will be examined independently of the other submodels. In this way we can assess the behaviour of each component.
2. The output of the model will be compared with data obtained from the chronosequences in a manner similar to the comparisons of the Shawnigan model with data from the Shawnigan experiment (Barclay and Hall 1986). The initial data from the chronosequences will provide an estimate of carbon distribution at one time. Subsequent measurements of a restricted number of features will provide estimates of fluxes of carbon. These will be used for comparison with model output.
3. The sensitivity analysis, in addition to providing information about the real system, also allows assessment of the behaviour of the model as a whole.

Deliverables

1. A gaming model to allow investigation of the actions of management interventions on carbon retention.
2. A sensitivity analysis to assess the effects of system parameters on the variables of interest.
3. A set of guidelines for managers to provide information on carbon retention resulting from various management scenarios.

References

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